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# (54) Title: LASER ALIGNMENT DEVICE

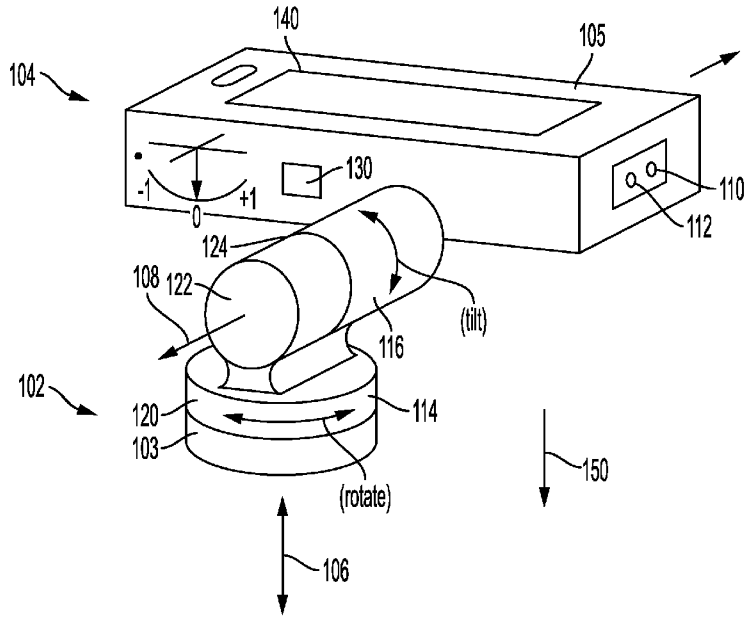


FIG. 1

**(57) Abstract:** Devices, systems, and methods for aligning large equipment, such as, for example, drill rigs. An apparatus includes a base, a subassembly, a first encoder, a second encoder, an orientation sensor, and one or more processors. The subassembly includes a housing and a range detector. The subassembly is movable relative to the base about a first axis and a second axis. The first encoder detects a degree of rotation about the first axis between the base and the subassembly. The second encoder detects a degree of rotation about the second axis between the base and the subassembly. The orientation sensor determines an orientation of a portion of the apparatus. At least one processor is in communication with the first encoder, the second encoder, and the orientation sensor.

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# LASER ALIGNMENT DEVICE

## CROSS-REFERENCE TO RELATED APPLICATIONS

**[0001]** This application claims priority to and the benefit of the filing date of U.S. Provisional Patent Application No. 62/983,205, filed February 28, 2020, the entirety of which is hereby incorporated by reference herein.

## FIELD

**[0002]** This application relates to devices, systems, and methods for aligning large equipment, such as, for example, drill rigs.

## BACKGROUND

**[0003]** Positioning a drill rig (e.g., an underground drill rig) at a desired location and in a desired orientation can be a difficult and time consuming process. Conventionally, a surveyor manually takes a plurality of measurements to determine reference points (e.g., on the walls of a mine). The surveyor marks the reference points, typically with respective spads (e.g., a nail with a hook or eye on the end). A first string is then hung between the spads, and additional strings are tied along the length of the first string. The additional strings have weights on the ends so that the additional strings hang in the same plane. Operators measure distances between said plane and portions of the drill rig, typically with a measuring tape that is visually approximated to be perpendicular to the plane, and move the rig as necessary to align the rig with the plane. The operator then re-measures the position of the drill rig with respect to the plane and repeats moving the drill rig and re-measuring as necessary until the drill rig is in position within select tolerances. The conventional process can be time consuming and ultimately inaccurate.

## SUMMARY

**[0004]** Described herein, in various aspects, is a laser alignment apparatus having a base. An instrumentation subassembly having a body can be coupled to the base. The body of the instrumentation subassembly can be movable relative to the base about a first axis and a second axis, wherein the first axis is not parallel to the second axis. A range detector can be

associated with the body. A first encoder can be configured to detect a degree of rotation about the first axis between the base and the body. A second encoder can be configured to detect a degree of rotation about the second axis between the base and the body. An orientation sensor can be configured to determine an orientation of a portion of the apparatus. The laser alignment apparatus can include at least one processor and a memory in communication with the at least one processor. The memory can comprise instructions that, when executed by the at least one processor, cause the laser alignment apparatus (or the at least one processor of the laser alignment apparatus) to: receive orientation data from the orientation sensor; receive a first distance measurement indicative of a distance between the range detector and a first reference point; receive a second distance measurement indicative of a distance between the range detector and a second reference point; receive a third distance measurement indicative of a distance between the range detector and a first point on a drill rig; receive rotation data from the first and second encoders, wherein the rotation data from the first and second encoders is associated with each of the first distance measurement, the second distance measurement, and the third distance measurement; and determine, based on the orientation data from the orientation sensor, the first distance measurement, the second distance measurement, and the rotation data from the first and second encoders, a spacing between the first point on the drill rig and a first vertical plane.

**[0005]** The first vertical plane can be parallel to a vertical reference plane that passes through the first reference point and the second reference point.

**[0006]** The first vertical plane can be coplanar with a vertical reference plane that passes through the first reference point and the second reference point.

**[0007]** The first vertical plane can be linearly offset from the vertical reference plane by a select distance.

**[0008]** The select distance can be a user input.

**[0009]** The memory can include instructions that, when executed by the at least one processor, cause the apparatus (or the at least one processor of the apparatus) to: cause an indication if the distance between the first point on the drill rig and the first vertical plane is within a tolerance.

[0010] The apparatus can further include a marker laser associated with the body of the instrumentation subassembly, and the processor can be configured to cause the indication if the distance between the first point on the drill rig and the first vertical plane is within the tolerance by activating the marker laser.

[0011] The first vertical plane can be angularly offset by a select angle from a vertical reference plane that passes through the first reference point and the second reference point.

[0012] The select angle can be a user input.

[0013] The memory can include instructions that, when executed by the at least one processor, cause the apparatus (or the at least one processor of the apparatus) to: receive a target distance measurement indicative of a distance to a target point; and receive further rotation data from the first and second encoders, wherein the further rotation data is associated with the target distance measurement, wherein the first vertical plane includes the target point.

[0014] The apparatus can further include an input device, wherein the memory comprises instructions that, when executed by the at least one processor, cause the apparatus (or the at least one processor of the apparatus) to receive an input of the tolerance.

[0015] The first axis can be perpendicular to the second axis.

[0016] The orientation sensor can be disposed within the body of the instrumentation subassembly and can be configured to determine an orientation of the body of the instrumentation subassembly.

[0017] The range detector can be a laser range detector.

[0018] The base can include a tripod.

[0019] The orientation sensor can include at least one gyroscope.

[0020] The orientation sensor can include at least one accelerometer.

[0021] The memory can include instructions that, when executed by the at least one processor, cause the apparatus (or the at least one processor of the apparatus) to: measure a setup time; and store the setup time in the memory.

**[0022]** Additional advantages of the disclosed apparatuses, systems, and methods will be set forth in part in the description that follows, and in part will be obvious from the description, or may be learned by practice of the invention. The advantages of the disclosed apparatuses, systems, and methods will be realized and attained by means of the elements and combinations particularly pointed out in the appended claims. It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as claimed.

## DESCRIPTION OF THE DRAWINGS

**[0023]** These and other features of the preferred embodiments of the disclosed apparatuses, systems, and methods will become more apparent in the detailed description in which reference is made to the appended drawings wherein:

**[0024]** FIG. 1 is a perspective view of a laser alignment device in accordance with embodiments disclosed herein.

**[0025]** FIG. 2 is a schematic of the laser alignment device in accordance with embodiments herein.

**[0026]** FIG. 3A is a top view schematic of the laser alignment device, a drill rig, and exemplary reference points and planes for positioning the drill rig in a parallel, offset position. FIG. 3B is a top view schematic of the laser alignment device, the drill rig, and exemplary reference points and planes for positioning the drill rig in an angularly offset position.

**[0027]** FIG. 4 illustrates a perspective view of a laser alignment device in accordance with embodiments disclosed herein.

**[0028]** FIG. 5 illustrates a partial rear perspective view of the laser alignment device of FIG. 4.

**[0029]** FIG. 6 illustrates a top view of the laser alignment device of FIG. 4, showing an exemplary screen and user interface of the device.

**[0030]** FIG. 7 illustrates a partial front perspective view of the laser alignment device of FIG. 4.

**[0031]** FIG. 8 illustrates a partial side view of the laser alignment device of FIG. 4.

**[0032]** FIGs. 9A-9C illustrate a flow chart for using the laser alignment device as disclosed herein.

**[0033]** FIG. 10 is a schematic of a computing device that can be used with the laser alignment device as disclosed herein.

## DETAILED DESCRIPTION

**[0034]** The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all embodiments of the invention are shown. Indeed, this invention may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Like numbers refer to like elements throughout. It is to be understood that this invention is not limited to the particular methodology and protocols described, as such may vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to limit the scope of the present invention.

**[0035]** Many modifications and other embodiments of the invention set forth herein will come to mind to one skilled in the art to which the invention pertains having the benefit of the teachings presented in the foregoing description and the associated drawings. Therefore, it is to be understood that the invention is not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

**[0036]** As used herein the singular forms "a," "an," and "the" include plural referents unless the context clearly dictates otherwise. For example, use of the term “an encoder” can refer to one or more of such encoders, and so forth.

**[0037]** All technical and scientific terms used herein have the same meaning as commonly understood to one of ordinary skill in the art to which this invention belongs unless clearly indicated otherwise.

[0038] As used herein, the terms “optional” or “optionally” mean that the subsequently described event or circumstance may or may not occur, and that the description includes instances where said event or circumstance occurs and instances where it does not.

[0039] As used herein, the term “at least one of” is intended to be synonymous with “one or more of.” For example, “at least one of A, B and C” explicitly includes only A, only B, only C, and combinations of each.

[0040] Ranges can be expressed herein as from “approximately” one particular value, and/or to “approximately” another particular value. When such a range is expressed, another aspect includes from the one particular value and/or to the other particular value. Similarly, when values are expressed as approximations, by use of the antecedent “approximately,” it will be understood that the particular value forms another aspect. It will be further understood that the endpoints of each of the ranges are significant both in relation to the other endpoint, and independently of the other endpoint. Optionally, in some aspects, when values are approximated by use of the antecedent “approximately,” it is contemplated that values within up to 15%, up to 10%, up to 5%, or up to 1% (above or below) of the particularly stated value can be included within the scope of those aspects.

[0041] The word “or” as used herein means any one member of a particular list and also includes any combination of members of that list.

[0042] It is to be understood that unless otherwise expressly stated, it is in no way intended that any method set forth herein be construed as requiring that its steps be performed in a specific order. Accordingly, where a method claim does not actually recite an order to be followed by its steps or it is not otherwise specifically stated in the claims or descriptions that the steps are to be limited to a specific order, it is in no way intended that an order be inferred, in any respect. This holds for any possible non-express basis for interpretation, including: matters of logic with respect to arrangement of steps or operational flow; plain meaning derived from grammatical organization or punctuation; and the number or type of aspects described in the specification.

[0043] The following description supplies specific details in order to provide a thorough understanding. Nevertheless, the skilled artisan would understand that the apparatus, system, and associated methods of using the apparatus can be implemented and used without employing these specific details. Indeed, the apparatus, system, and associated methods can be placed into practice by modifying the illustrated apparatus, system, and associated methods and can be used in conjunction with any other apparatus and techniques conventionally used in the industry.

**[0044]** Disclosed herein, in various aspects and with reference to FIGs. 1 and 2, is a laser alignment device 100. The alignment device 100 can comprise a base 102 and an instrumentation subassembly 104 having a body 105 (e.g., housing) that is pivotable with respect to the base 102 about a first axis 106 and a second axis 108. In exemplary aspects, the instrumentation subassembly 104 can comprise a structure that couples to the base 102 and permits pivotal movement of the body 105 with respect to the base. For example, a first pivotal coupling 120 can couple the base 102 to a linking portion 122, and a second pivotal coupling 124 can couple the linking portion 122 to the body 105 of the instrumentation subassembly 104. Optionally, the linking portion can be an elbow structure as shown in FIG. 1. The first axis 106 and second axis 108 can be angled with respect to each other (i.e., not parallel) and can optionally be perpendicular or approximately perpendicular to each other. In some optional aspects, the first axis 106 can be oriented approximately vertically or vertically, and the second axis 108 can be oriented approximately horizontally or horizontally.

**[0045]** As shown in FIG. 1, the base 102 can comprise a base body 103, which can be any fixed structure. Optionally, the base body can be secured to or comprise stationary equipment for use in drilling or mining operations. As shown, the base body 103 can be configured for attachment to a lower portion of the instrumentation subassembly 104, such as, for example, a first pivotal coupling 120. In exemplary aspects, and as shown in FIGS. 4-8, the base 102 can comprise a stand 190, such as, for example, a tripod, a cart with locking wheels, or other structure that is configured to allow the base 102 to remain in a fixed position during operation of the alignment device 100. In exemplary aspects, the stand 190 can be configured to securely engage the base body 103. For example, the base body 103 can comprise one or more engagement features (such as those for a conventional camera) that can releasably engage the stand 190. In some aspects, the engagement features can be portions of a universal bracket that can couple to a conventional stand. In further aspects, the base body 103 can be permanently coupled to, or integral to, the stand 190. In still further aspects, it is contemplated that the stand 190 can directly engage the instrumentation subassembly 104 without the use of a base body 103.

[0046] The instrumentation subassembly 104 can comprise a range detector 110 (e.g., a laser range detector). The range detector 110 can emit a laser beam toward a surface and determine the distance to the surface based on the reflection time. The range detector can optionally use a beam in the visible spectrum. In further optional aspects, the range detector can emit a beam outside of the visible spectrum, and the range detector can further comprise a visible guide laser (e.g., optionally, a red laser) that indicates where the laser range detector is aimed. The subassembly 104 can optionally further comprise a marking laser 112 that can be activated and deactivated based on various conditions, as further disclosed herein. The marking laser 112 can comprise, for example, a green diode laser. However, lasers having other color profiles can also be used. Preferably, it is contemplated that the color of the guide laser and the marking laser can be different to allow a user to easily distinguish between the two.

[0047] The instrumentation subassembly 104 can comprise an orientation sensor 130 (e.g., a gyroscope, an inertial measurement unit, at least one accelerometer, or 3-axis accelerometer). The orientation sensor 130 can be configured to determine the direction (e.g., vector) of gravity. In exemplary aspects, the range detector 110, the marking laser 112, the orientation sensor 130, and various other elements disclosed herein can be disposed within the body 105 of the instrumentation subassembly 104. In further aspects, the body 105 of the instrumentation subassembly 104 can be calibrated to a known orientation, and one or more accelerometers can be used to determine movement from the known orientation so that the alignment device can determine the orientation of the instrumentation subassembly 104 relative to the direction of gravity (or other known reference orientation that can be associated with the direction of gravity).

[0048] The instrumentation subassembly 104 can further comprise sensors that are configured to measure rotation of the body 105 of the instrumentation subassembly relative to the first and second axes 106, 108. In exemplary aspects, the sensors can comprise a first encoder 114 that measures the rotation of the body 105 with respect to the base 102 about the first axis 106 (e.g., measuring the rotation between the base and the linking portion 122). A second encoder 116 can measure the rotation of the body 105 with respect to the base 102 about the second axis 108 (e.g., measuring the rotation between the base 105 and the linking portion 122). The encoders can be, for example, mechanical (e.g., potentiometers), magnetic, (e.g., Hall Effect encoders), or optical encoders. As can be understood, the measured rotation of the body 105 corresponds or approximately corresponds to the rotation of components fixedly secured to or within the body (e.g., housing). Thus, when the rotation or orientation of the body 105 is referenced herein, it is understood that such rotation or orientation is also applicable to any components that are fixedly associated with the body. In some aspects, it is contemplated that the body 105 can be provided as a single enclosure or as multiple fixedly attached components (e.g., enclosures, receptacles, or other structures).

**[0049]** As shown in FIG. 2, the instrumentation subassembly 104 can further comprise a power source 132 and a computing device 134 that comprises one or more processors 136 and a memory 138 in communication with the one or more processors 136. The instrumentation subassembly 104 can further comprise a display 140 and an input device 142. In some aspects, the display 140 and input device 142 can collectively be embodied as a touch screen. In further aspects, the input device 142 can comprise one or more push buttons. Each of the power source 132, computing device 134, display 140, and input device 142 can be within or attached to the body 105 (FIG. 1). The memory can comprise instructions that, when executed by the one or more processors 136, can cause the processor to receive data from the orientation sensor 130, encoders 114, 116, and range detector 110 and provide routines for aligning a device (e.g., a drill rig) with respect to known reference points (e.g., points that a surveyor has marked with, for example, paint or spads).

**[0050]** Although this application discloses in detail how the alignment device 100 can be used to align a drill rig, it should be understood that the alignment device can be used to align various equipment, such as, for example, a rod handler. In further aspects, it is contemplated that the alignment device can enable alignment and leveling of a platform upon which the drill rig can be placed during drilling.

**[0051]** Referring to FIGs. 3A and 9A, the alignment device 100 can be used to orient a drill rig 200 (FIG. 3A). In one exemplary method, an operator can position the alignment device 100 on a firm surface. The operator can start up the alignment device 100. The alignment device 100 can prompt the operator to level the body 105 of the instrumentation subassembly 104 (or otherwise establish an orientation of the body 105 relative to a direction of gravity). For example, a virtual bubble level (or other indication of orientation of the body 105) can be provided on the display 140 of the instrumentation subassembly 104. The virtual bubble level can receive orientation data from the orientation sensor 130 and can indicate to the operator a direction and angular amount to rotate the body 105 of the subassembly 104 about the first and second axes 106, 108 in order to level the body 105. Once the body 105 is leveled, the alignment device 100 can prompt the operator to stop touching the alignment device for a duration (e.g., three seconds) while the alignment device stores initial encoder data from the first encoder 114 and second encoder 116. Said stored initial encoder data can correspond to the orientation of the body 105 of the subassembly 104 when the device is level (or otherwise at a known orientation relative to the direction of gravity). Thus, in some aspects, leveling of the alignment device 100 can enable the alignment device 100 to determine a gravity vector 150 (FIG. 1) relative to the initial encoder data. In this way, the encoder data can be correlated to the known orientation of the body 105 of the subassembly 104 relative to gravity. As disclosed herein, the gravity vector can be used to as a component for defining one or more vertical planes. In further optional aspects, the first encoder 114 and second encoder 116 can be absolute encoders, and the step of orienting the device can be omitted. The alignment device 100 can then enable the operator to input or select a hole identifier.

**[0052]** Referring to FIG. 3A, the alignment device 100 can prompt the operator to scan a first reference point 302 and then a second reference point 304. The first and second reference points 302, 304 can be, for example, surveyor marked points in an underground mine or other landmarks having known or fixed locations. The operator can move the body 105 of the subassembly 104 about the first axis and/or second axis until the operator sees a laser spot from the range sensor 110 on the first known reference point 302. As can be seen in FIG. 5, first and second fine adjustment knobs 180 and 182 can enable the operator to make small angular adjustments of body 105 of the subassembly 104 with respect to the first axis 106 and second axis 108, respectively. The operator can, via input through the input device 142, cause the alignment device 100 to store and associate the first and second encoder positions for the first reference point 302 and the distance to the first reference point 302. The first and second encoder positions can be absolute measurements or measurements relative to the encoder positions when the body 105 of the subassembly 104 is level. The operator can then move the body 105 of the subassembly 104 about the first axis and/or second axis until the operator sees a laser spot from the range sensor 110 on the second known reference point 304. The operator can, via input through the input device 142, cause the alignment device 100 to store and associate the first and second encoder positions for the second reference point 304 and the distance to the second reference point 304.

[0053] Using the orientation of the body 105 of the subassembly 104 from its leveled, initialized position and the data from the encoders, the relative spatial relationships between the alignment device, the first reference point, and the second reference point can be determined. That is, spatial positions can be determined with trigonometric relationships between the alignment device and points that the alignment device measures. For example, the position of the first and second reference points 302, 304 can be known in spherical coordinates ($r$, $\theta$, $\varphi$) with respect to the alignment device, wherein the distance measurements can represent the radius, $r$, the first encoder can provide the polar angle, $\theta$, and the second encoder can provide the azimuthal angle, $\varphi$.

[0054] The first and second reference points 302, 304 and the gravity vector 150 can define a vertical reference plane 300. That is, it should be understood that only one vertical plane (parallel to the gravity vector 150) can extend through any two points in space. Thus, any further distance measurements (e.g., distance measurements to the drill rig 200) can be compared to the reference plane 300. Using these comparative measurements, the drill rig 200 can be aligned on the vertical reference plane 300, offset from the vertical reference plane, and/or angled with respect to the vertical reference plane.

[0055] Referring also to FIG. 9B, in some aspects, the alignment device can provide the operator with a menu for selecting various alignment options. For example, display and input device (e.g., touchscreen) of the alignment device can provide a menu for alignment options including: aligning the rig with the reference plane, aligning the rig parallel to, but offset from, the reference plane by an input distance, aligning the rig parallel to, but offset from, the reference plane and including a target, or aligning the rig angularly offset from the reference plane by a select angle in a clockwise or counterclockwise direction. In response to a selection, the alignment device can prompt the operator to take steps to align the drill rig in accordance with the selection.

[0056] It is contemplated that the reference plane 300 can be a conceptual plane that is provided for understanding the operation of the alignment device 100, and the actual plane does not need to be determined and defined as an intermediate step in order to provide further calculations disclosed herein. In practice, the raw measurement data (e.g., encoder data and associated distance measurements) can be stored, for example, in a matrix, and the raw data can be input into calculations to provide outputs, examples of which are further disclosed herein. The calculations can be performed using known trigonometric and algebraic formulae in conjunction with known computational methods, such as, for example, linear algebra.

**[0057]** In some aspects, the operator can select from the menu an option to align the drill rig along the reference plane so that the drill rig is parallel to the reference plane and not offset from the reference plane. The operator can then aim the alignment device 100 at a first point 312 on the drill rig. The range detector 110 can measure the distance to the first point on the drill rig, and the alignment device 100 can, using the measurement of the distance to the first point on the drill rig and the data from the first and second encoder, determine the spacing between the first point 312 on the drill rig and the reference plane. In various aspects, the alignment device 100 can indicate to the operator the spacing between the first point 312 on the drill rig (or any point on the drill rig at which the alignment device is pointed) and the reference plane. For example, in some aspects, the alignment device 100 can output on the display 140 said spacing. In further aspects, the alignment device 100 can activate the marking laser 112 when the spacing is within a tolerance and deactivate the marking laser when the spacing is outside of the tolerance (or otherwise provide an indication). In various aspects, the indication can comprise turning on the marking laser when the spacing between the point on the rig at which the alignment device is pointed (e.g., the first point 312) and the reference plane (or other alignment plane) is within a tolerance. In further aspects, the indication can comprise turning off the marking laser when the spacing between the point on the rig at which the alignment device is pointed (e.g., the first point 312) and the reference plane (or other alignment plane) is within a tolerance. In still further aspects, the indication can comprise causing the marking laser to flash or change a rate of flashing based on the spacing. For example, the marking laser can turn on and off at a first frequency when the spacing is within a first tolerance, at a second frequency when the spacing is within a third tolerance, and the marking laser can stay solid when the spacing is within a third tolerance. It is contemplated that the tolerance can be set by the operator (e.g. via the touchscreen). In further aspects, the alignment device 100 can activate an audible alarm or provide a visual output on the display when the spacing is within the tolerance. In further aspects, the audible alarm can change based on the spacing. For example, a series of beeps with long pauses therebetween correspond to a larger spacing, and a series of beeps with short pauses therebetween correspond to a smaller spacing. Using such indications, the operator can move the drill rig (and, optionally, realigning the body 105 of the subassembly 104 to continually measure the same point on the drill rig) until the alignment device 100 indicates that the first point on the drill rig is within a select tolerance 310 of the reference plane. The select tolerance can be, for example, a predetermined setting (distance) or a user input distance.

**[0058]** Once the first point on the rig is positioned within the tolerance, the operator can reorient the body 105 of the subassembly 104 to point the range detector at a second point 314 on the rig. The second point 314 can optionally be on the same planar surface 201 (optionally, a vertically planar surface) or another planar surface that is coplanar with the surface on which the first point 312 is taken. For example, the first point 312 can be a point near the front end of the drill rig, and the second point can be a point near the rear of the drill rig. The operator can move the drill rig until the second point 314 on the rig is within the select tolerance of the reference plane. The operator can then reorient the body 105 of the subassembly 104 to point the range detector back at the first point 312 to verify that in moving the rig to align the second point, the first point is still in alignment. Thus, it can be understood that when the first point 312 on the rig and second point 314 on the rig are aligned with the reference plane, the planar surface 201 is aligned with the reference plane.

**[0059]** Optionally, the planar surface 201 can be parallel to the drilling axis 202 of the drill rig 200. Thus, when the planar surface 201 is coplanar with the reference plane, the drilling axis 202 can be known to be parallel to the reference plane and offset by the distance between the planar surface 201 and the drilling axis 202.

**[0060]** It is contemplated that the first and second points on the drill rig 200 need not be specific points on the drill rig. Rather, it is contemplated that any two points (that are sufficiently spaced along the drill rig, e.g., a point near the front end of the drill rig and a point near the rear end of the drill rig) can indicate alignment with the reference plane. Further, it is contemplated that, as the drill rig is moved into position, many points along the drill rig can be used for aligning the rig. For example, a measurement of a first point on the drill rig can indicate that the front end needs to be moved by a half of a meter, and a measurement of a second point on the drill rig can indicated that the rear end is in position and does not need to be moved. The operators can move the front end of the drill rig. The operators can then re-check the positions of the front and rear ends by picking two more points that are not necessarily the same as the first two points but are representative of the positions of the front and rear ends. If, in moving the rear end, the front end has moved out of position, the front end can be moved, and the operators can iteratively move the drill rig and take measurements until the front and rear ends are in alignment.

**[0061]** In some aspects and as illustrated in FIG. 3A and 9B, the alignment device 100 can enable the operator to align the rig in an alignment plane 308 that is parallel to the reference plane 300 and offset from the reference plane by a select distance 306. For example, upon receiving from the operator the menu option to align the rig parallel to, and offset from, the reference plane, the alignment device can prompt the operator to select the offset distance 306 and the direction of offset (e.g., toward or away from the alignment device). The alignment device can then define the alignment plane 308. Then, the operator can aim the laser at points on the rig and, in the same manner described above, the alignment device can indicate whether the points on the drill rig are aligned with the alignment plane 308 within the select tolerance. For example, the alignment device can be aimed at the rear of the rig, and as the rig is moved within the tolerance of the alignment plane 308, the marker laser 112 can activate (or otherwise provide an indication) to indicate the proper alignment. The alignment device can be aimed at the front of the rig, and the marker laser can activate (or otherwise provide an indication) when the front of the rig (at the point where the laser is aimed) is within the tolerance of the alignment plane 308. The rear and front of the rig can be re-checked and moved as necessary until both ends are aligned with the alignment plane 308.

**[0062]** In further aspects, the alignment device can enable the operator to align the rig in an alignment plane 308 that includes a target point 320 (e.g., a survey marker) and is parallel to the reference plane. Thus, the rig can be aligned parallel to, and offset from, the reference plane by the distance between the target point and the reference plane. For example, upon receiving from the operator the menu option to align the rig parallel to and offset from the reference plane based on the target point, the alignment device (e.g., through the display) can prompt the operator to aim the alignment device at the target point and provide an input (e.g., press a button) once the alignment device is aimed at the target point 320. Upon the operator aiming the device at the target point and providing the input, the alignment device can store the measurement of the distance from the alignment device to the target point as well as the encoder data from the first and second encoders. The alignment device can then define the alignment plane 308 based on the collected data and geometric (trigonometric) relationships so that the alignment plane is parallel to the reference plane and includes the target point 320. Then, the operator can aim the laser at points on the rig and, in the same manner described above, the alignment device can indicate whether the points on the drill rig are aligned with the alignment plane 308 within the select tolerance. For example, the alignment device can be aimed at the rear of the rig, and as the rig is moved within the tolerance of the alignment plane 308, the marker laser 112 can activate (or otherwise provide an indication) to indicate the proper alignment. The alignment device can be aimed at the front of the rig, and the marker laser can activate (or otherwise provide an indication) when the front of the drill rig (where the laser is aimed) is within the tolerance of the alignment plane 308. The rear and front of the rig can be re-checked and moved as necessary until both ends are aligned with the alignment plane.

**[0063]** In further aspects and with reference to FIG. 3B and 9C, the alignment device can enable the operator to align the rig with an alignment plane 308 that is angularly offset from the reference plane. For example, upon receiving from the operator the selected menu option to align the rig angularly offset from the reference plane, the alignment device can prompt the user to input an angular offset ($\alpha$) and a rotational direction (e.g., clockwise or counterclockwise). The device can then prompt the user to select a target point 320 (e.g., a survey marker). For example, the device can prompt the user to point the laser marker at the target point 320 and press a button or otherwise cause the alignment device 100 to capture the location of the target point. In further aspects, the target point 320 can be any point about which the rig is to be pivoted. For example, a geometric coordinate (e.g., a Cartesian coordinate or a spherical coordinate) can be input into the device 100 for use as the target point 320. Upon receiving the angular offset, rotational direction, and target point, the alignment device can determine the alignment plane 308 that includes the target point 320 and is angularly offset from the reference plane 300 by the select angular offset. Accordingly, the target point 320 can serve as the pivot point about which the plane is pivoted by the select angular offset relative to the alignment plane 308. Then, the operator can aim the laser at points (e.g., point 312 and 314) on the rig 200 (e.g., on the planar surface 201) and, in the same manner described above, the alignment device can indicate whether the points on the drill rig are aligned with the alignment plane 308 within the select tolerance. For example, the alignment device can be aimed at the rear of the rig, and as the rig is moved within the tolerance of the alignment plane, the marker laser 112 can activate (or otherwise provide an indication) to indicate the proper alignment (e.g., within the tolerance 310). The alignment device can be aimed at the front of the rig, and the marker laser can activate (or otherwise provide an indication) when the front of the rig (where the laser is aimed) is within the tolerance of the alignment plane. The rear and front of the rig can be re-checked and moved as necessary until both ends are aligned with the alignment plane.

**[0064]** It is further contemplated that the alignment device can be configured to enable the operator to align the rig with both a linear and angular offset from the reference plane. For example, the alignment device can prompt the user to input an angular offset and a linear offset from the target point 320.

**[0065]** In still further aspects, it can be beneficial to align the drill rig in a select azimuthal orientation, while the lateral offset in any direction can be generally unimportant. For example, in contrast with other embodiments described herein, the offset of the alignment plane may be unimportant. Thus, it is contemplated that the laser aligner can enable alignment of the drill rig parallel to the reference plane or a plane that is offset from the reference plane by a select angle.

**[0066]** In one aspect, after receiving the measurements of the first and second reference points, the laser aligner can provide a menu option to align the drill rig with the reference plane with the linear offset ignored. Upon receiving a selection of that menu option from the operator, the laser aligner can be pointed at the drill rig, and the laser aligner can provide real-time feedback of the calculated distance between the drill rig and the reference plane. For example, the display can output the distance calculation. Using this real-time calculated distance, the operators can aim the laser aligner at multiple spaced points on coplanar surfaces on the drill rig, and move the drill rig until the different points on the coplanar surfaces have the same distance reading to the reference plane. Once the operators have the drill rig in proper alignment, the laser aligner can enable a final check. The laser aligner can prompt the operator to take a first measurement at a first point and then a second measurement at a second point. The laser aligner can determine whether the first and second points are equally spaced from the reference plane and whether the first and second points are spaced sufficiently from each other in a horizontal direction in order to determine alignment. If the first and second points are sufficiently spaced from each other and at an equal spacing from the reference plane (within a select tolerance), the laser aligner can indicate that the drill rig is aligned and store and display the offset distance between the drill rig and the reference plane.

[0067] In another aspect, the after receiving the measurements of the first and second reference points, the laser aligner can provide a menu option to align the drill rig parallel to an angularly offset plane that is angularly offset relative to the reference plane with the linear offset ignored. Upon receiving a selection of that menu option from the operator, the laser aligner can prompt the user to input the angular offset and the offset direction (clockwise or counterclockwise). The laser aligner can then prompt the user to aim the laser aligner at a point through which the angularly offset reference plane passes (e.g., a target, such as, for example, a drill collar location). In further aspects, the laser aligner can user any arbitrary point (e.g., the first reference point) as the point through which the angularly offset reference plane passes, as the position of the plane can be arbitrary. The laser aligner can then be used to determine the distance between points on the drill rig and the angularly offset reference plane. That is, the laser aligner can provide real-time feedback of the calculated distance between the drill rig and the angularly offset reference plane. For example, the display can output the distance calculation. Using this real-time calculated distance, the operators can aim the laser aligner at multiple spaced points on coplanar surfaces on the drill rig, and move the drill rig until the different points on the coplanar surfaces have the same distance reading to the angularly offset reference plane. Once the operators have the drill rig in proper alignment, the laser aligner can enable a final check. The laser aligner can prompt the operator to take a first measurement at a first point and then a second measurement at a second point. The laser aligner can determine whether the first and second points are equally spaced from the angularly offset reference plane and whether the first and second points are spaced sufficiently from each other in a horizontal direction in order to determine alignment. If the first and second points are sufficiently spaced from each other and at an equal spacing from the angularly offset reference plane (within a select tolerance), the laser aligner can indicate that the drill rig is aligned and store and display the offset distance between the drill rig and the angularly offset reference plane.

[0068] In further aspects, the alignment device can collect and store various other relevant data. For example, the alignment device can enable the operator to input a hole identifier (name, location, reference, etc.). The alignment device further display or output an audit log upon completion of the rig alignment (as shown in FIGs 9B and 9C). For example, the alignment device can record a duration of the alignment process, such as, for example, the time lapsed from scanning of the first reference point to the operator input indicating that the rig is aligned. The audit log can optionally comprise the hole identifier, time lapsed, and corresponding any orientation data (e.g., angular or linear offsets from reference planes).

**[0069]** The alignment device can eliminate the manual process of setting up and aligning a drill rig using string lines and plumbs. The device can use a safe, low powered red laser to measure the locations of the spads (e.g., front and back sights). Once the spads are measured, a virtual string line can be created to which the rig can be aligned. The marking laser (e.g., a green indicator laser) can activate (or otherwise provide an indication) to confirm that the rig, or a portion thereof, is correctly aligned before drilling.

**[0070]** Advantages can include elimination of waiting for survey marks. Existing surveyed reference points can be used to create new lines according to drill plans and eliminate long wait times for mine surveyors to provide new front and back sights. Rig movement can be safer, as measurements can be taken from a distance. For example, the alignment device can eliminate any need to climb on the drill rig or surrounding surfaces. Rig movement can be performed more quickly than conventional measurement and alignment methods. Collar accuracy can be increased. For example, the alignment device can enable one degree accuracy in azimuth and 0.3% error or less for every ten meters in distance. Setup errors can further be eliminated. The log file can create a digital log that can facilitate auditing. The log file can be tailored for productivity monitoring and improvements.

**[0071]** The alignment device can optionally be designed to IP 67 standards. The alignment device can comprise a seven-inch touch screen display with a responsive, glove friendly user interface. The alignment device can comprise lithium ion batteries that can be charged via USB and can provide at least five hours of use. The alignment device can comprise a lifting handle for mounting to an industry-standard Leica GST05 survey tripod. Precision encoders with fine positioning adjustment knobs can control head rotation and up/down adjustments. The audit log for productivity tracking can be downloaded via USB or other protocol (for example, Bluetooth, WiFi, or other wireless transmission protocols). The alignment device can be provided in a pelican case for safe storage and transportation.

**[0072]** It is contemplated that in further aspects, the laser aligner can be positioned on the drill rig. For example, the laser aligner can be coupled to the drill rig so that the drilling axis can be known with respect to the laser aligner. In this way, it can be understood that distance and angle measurements can be taken from the drill rig to the reference points, and the computing device 1001 can be configured to determine the orientation of the drill rig with respect to the reference points using similar geometric and numerical calculations.

Computing Device

**[0073]** FIG. 10 shows a system 1000 including an exemplary configuration of a computing device 1001 for use with the alignment device 100. In some aspects, the computing device 1001 can be integral to the alignment device 100 and can comprise the processor 136 and the memory 138. Thus, it is contemplated that computing device 134 can have a configuration as described below with respect to computing device 1001. In further aspects, it is contemplated that a separate computing device, such as, for example, a tablet, smartphone, laptop, or desktop computer can communicate with the alignment device 100 and can enable the operator to interface with the alignment device 100. For example, in some aspects, computing device 134 can communicate with computing device 1001 using conventional protocols, such as, without limitation, USB, Bluetooth, WiFi, and other wired or wireless protocols as are known in the art.

**[0074]** The computing device 1001 may comprise one or more processors 1003, a system memory 1012, and a bus 1013 that couples various components of the computing device 1001 including the one or more processors 1003 to the system memory 1012. In the case of multiple processors 1003, the computing device 1001 may utilize parallel computing.

**[0075]** The bus 1013 may comprise one or more of several possible types of bus structures, such as a memory bus, memory controller, a peripheral bus, an accelerated graphics port, and a processor or local bus using any of a variety of bus architectures.

**[0076]** The computing device 1001 may operate on and/or comprise a variety of computer readable media (e.g., non-transitory). Computer readable media may be any available media that is accessible by the computing device 1001 and comprises, non-transitory, volatile and/or non-volatile media, removable and non-removable media. The system memory 1012 has computer readable media in the form of volatile memory, such as random access memory (RAM), and/or non-volatile memory, such as read only memory (ROM). The system memory 1012 may store data such as encoder data 1007 (i.e., data from signals received by the electrodes) and/or program modules such as operating system 1005 and spatial calculation software 1006 that are accessible to and/or are operated on by the one or more processors 1003.

**[0077]** The computing device 1001 may also comprise other removable/non-removable, volatile/non-volatile computer storage media. The mass storage device 1004 may provide non-volatile storage of computer code, computer readable instructions, data structures, program modules, and other data for the computing device 1001. The mass storage device 1004 may be a hard disk, a removable magnetic disk, a removable optical disk, magnetic cassettes or other magnetic storage devices, flash memory cards, CD-ROM, digital versatile disks (DVD) or other optical storage, random access memories (RAM), read only memories (ROM), electrically erasable programmable read-only memory (EEPROM), and the like.

**[0078]** Any number of program modules may be stored on the mass storage device 1004. An operating system 1005 and spatial calculation software 1006 may be stored on the mass storage device 1004. One or more of the operating system 1005 and spatial calculation software 1006 (or some combination thereof) may comprise program modules and the spatial calculation software 1006. Encoder data 1007 may also be stored on the mass storage device 1004. Encoder data 1007 may be stored in any of one or more databases known in the art. The databases may be centralized or distributed across multiple locations within the network 1015.

**[0079]** A user may enter commands and information into the computing device 1001 using an input device (not shown). Such input devices comprise, but are not limited to, a keyboard, touchscreen display, pointing device (e.g., a computer mouse, remote control), a microphone, a joystick, a scanner, tactile input devices such as gloves, and other body coverings, motion sensor, speech recognition, and the like. These and other input devices may be connected to the one or more processors 1003 using a human machine interface 1002 that is coupled to the bus 1013, but may be connected by other interface and bus structures, such as a parallel port, game port, an IEEE 1394 Port (also known as a Firewire port), a serial port, network adapter 1008, and/or a universal serial bus (USB).

**[0080]** A display device 1011 may also be connected to the bus 1013 using an interface, such as a display adapter 1009. It is contemplated that the computing device 1001 may have more than one display adapter 1009 and the computing device 1001 may have more than one display device 1011. A display device 1011 may be a monitor, an LCD (Liquid Crystal

Display), light emitting diode (LED) display, television, smart lens, smart glass, and/ or a projector. In addition to the display device 1011, other output peripheral devices may comprise components such as speakers (not shown) and a printer (not shown) which may be connected to the computing device 1001 using Input/Output Interface 1010. Any step and/or result of the methods may be output (or caused to be output) in any form to an output device. Such output may be any form of visual representation, including, but not limited to, textual, graphical, animation, audio, tactile, and the like. The display 1011 and computing device 1001 may be part of one device, or separate devices.

**[0081]** The computing device 1001 may operate in a networked environment using logical connections to one or more remote computing devices 1014a,b,c. A remote computing device 1014a,b,c may be a personal computer, computing station (e.g., workstation), portable computer (e.g., laptop, mobile phone, tablet device), smart device (e.g., smartphone, smart watch, activity tracker, smart apparel, smart accessory), security and/or monitoring device, a server, a router, a network computer, a peer device, edge device or other common network node, and so on. Logical connections between the computing device 1001 and a remote computing device 1014a,b,c may be made using a network 1015, such as a local area network (LAN) and/or a general wide area network (WAN) , or a Cloud-based network. Such network connections may be through a network adapter 1008. A network adapter 1008 may be implemented in both wired and wireless environments. Such networking environments are conventional and commonplace in dwellings, offices, enterprise-wide computer networks, intranets, and the Internet. It is contemplated that the remote computing devices 1014a,b,c can optionally have some or all of the components disclosed as being part of computing device 1001. In various further aspects, it is contemplated that some or all aspects of data processing described herein can be performed via cloud computing on one or more servers or other remote computing devices. Accordingly, at least a portion of the system 1000 can be configured with internet connectivity.

## EXEMPLARY ASPECTS

**[0082]** In view of the described products, systems, and methods and variations thereof, herein below are described certain more particularly described aspects of the invention. These particularly recited aspects should not however be interpreted to have any limiting effect on any different claims containing different or more general teachings described herein, or that the "particular" aspects are somehow limited in some way other than the inherent meanings of the language literally used therein.

**[0083]** Aspect 1: An apparatus comprising: a base; an instrumentation subassembly having a body, wherein the instrumentation subassembly is coupled to the base, wherein the body of the instrumentation subassembly is movable relative to the base about a first axis and a second axis, wherein the first axis is not parallel to the second axis, the instrumentation subassembly comprising: a range detector associated with the body; a first encoder that is configured to detect a degree of rotation about the first axis between the base and the body; a second encoder that is configured to detect a degree of rotation about the second axis between the base and the body; an orientation sensor that is configured to determine an orientation of a portion of the apparatus; at least one processor; and a memory in communication with the at least one processor, wherein the memory comprises instructions that, when executed by the at least one processor, cause the at least one processor to: receive orientation data from the orientation sensor; receive a first distance measurement indicative of a distance between the range detector and a first reference point; receive a second distance measurement indicative of a distance between the range detector and a second reference point; receive a third distance measurement indicative of a distance between the range detector and a first point on a drill rig; receive rotation data from the first and second encoders, wherein the rotation data from the first and second encoders is associated with each of the first distance measurement, the second distance measurement, and the third distance measurement; and determine, based on the orientation data from the orientation sensor, the first distance measurement, the second distance measurement, and the rotation data from the first and second encoders, a spacing between the first point on the drill rig and a first vertical plane.

**[0084]** Aspect 2: The apparatus of aspect 1, wherein the first vertical plane is parallel to a vertical reference plane that passes through the first reference point and the second reference point.

**[0085]** Aspect 3: The apparatus of aspect 1, wherein the first vertical plane is coplanar with a vertical reference plane that passes through the first reference point and the second reference point.

**[0086]** Aspect 4: The apparatus of aspect 2, wherein the first vertical plane is linearly offset from the vertical reference plane by a select distance.

**[0087]** Aspect 5: The apparatus of claim 4, wherein the select distance is a user input.

**[0088]** Aspect 6: The apparatus of any one of aspects 2-5, wherein the memory comprises instructions that, when executed by the at least one processor, cause the at least one processor to: cause an indication if the distance between the first point on the drill rig and the first vertical plane is within a tolerance.

**[0089]** Aspect 7: The apparatus of aspect 6, further comprising a marker laser associated with the body of the instrumentation assembly, wherein the processor is configured to cause the indication if the distance between the first point on the drill rig and the first vertical plane is within the tolerance by activating the marker laser.

**[0090]** Aspect 8: The apparatus of claim 1, wherein the first vertical plane is angularly offset by a select angle from a vertical reference plane that passes through the first reference point and the second reference point.

**[0091]** Aspect 9: The apparatus as in aspect 8, wherein the first vertical plane includes a target point.

**[0092]** Aspect 10: The apparatus as in aspect 8 or aspect 9, wherein the select angle is a user input.

**[0093]** Aspect 11: The apparatus of any one of aspects 2 or 6-9, wherein the memory comprises instructions that, when executed by the at least one processor, cause the at least one processor to: receive a target distance measurement indicative of a distance to a target point; and receive further rotation data from the first and second encoders, wherein the further rotation data is associated with the target distance measurement, wherein the first vertical plane includes the target point.

**[0094]** Aspect 12: The apparatus as in claim any one of the preceding aspects, further comprising an input device, wherein the memory comprises instructions that, when executed by the at least one processor, cause the at least one processor to receive an input of the tolerance.

**[0095]** Aspect 13: The apparatus of any one of the preceding aspects, wherein the first axis is perpendicular to the second axis.

[0096] Aspect 14: The apparatus of any one of the preceding aspects, wherein the orientations sensor is disposed within the body of the instrumentation subassembly, and wherein the orientation sensor is configured to determine an orientation of the body of the instrumentation subassembly.

[0097] Aspect 15: The apparatus of any one of the preceding aspects, wherein the range detector is a laser range detector.

[0098] Aspect 16: The apparatus of any one of the preceding aspects, wherein the base comprises a tripod.

[0099] Aspect 17: The apparatus of any one of the preceding aspects, wherein the orientation sensor comprises at least one gyroscope.

[00100] Aspect 18: The apparatus of any one of the preceding aspects, wherein the orientation sensor comprises at least one accelerometer.

[00101] Aspect 19: The apparatus of any one of the preceding aspects, wherein the memory comprises instructions that, when executed by the at least one processor, cause the at least one processor to: measure a setup time; and store the setup time in the memory.

[00102] Aspect 20: A method of using the apparatus of any one of the preceding claims to align a drill rig with respect to a formation, the method comprising: aiming the range detector at the first reference point; aiming the range detector at the second reference point; aiming the range detector at the first point on the drill rig; and adjusting a position of at least a portion of the drill rig based on an output from the apparatus.

[00103] Aspect 21: The method of aspect 20, wherein the output comprises an activation or an absence of activation of the marker laser.

[00104] Aspect 22: The method of aspect 20 or aspect 21, wherein the apparatus comprises a display, wherein the output comprises the spacing displayed on the display.

[00105] Aspect 23: The method of any one of aspects 20-22, further comprising: aiming the range detector at the a second point on the drill rig; and adjusting a position of at least a second portion of the drill rig based on a second output from the apparatus.

**[00106]** Aspect 24: The method of any one of aspects 20-23, further comprising: inputting, with the input device, at least one of a linear offset or an angular offset.

**[00107]** Aspect 25: The method of any one of aspects 20-24, further comprising causing the apparatus to store in the memory the first distance measurement and the rotation data from the first and second encoders.

**[00108]** Aspect 26: An apparatus comprising: a base; an instrumentation subassembly having a body, wherein the instrumentation subassembly is coupled to the base, and wherein the body of the instrumentation subassembly is movable relative to the base about a first axis and a second axis, wherein the first axis is not parallel to the second axis, the instrumentation subassembly comprising: a range detector associated with the body; a first encoder that is configured to detect a degree of rotation about the first axis between the base and the subassembly; a second encoder that is configured to detect a degree of rotation about the second axis between the base and the subassembly; an orientation sensor that is configured to determine an orientation of a portion of the apparatus; and one or more processors, wherein at least one processor of the one or more processors is in communication with the first encoder, the second encoder, and the orientation sensor.

**[00109]** Although the foregoing invention has been described in some detail by way of illustration and example for purposes of clarity of understanding, certain changes and modifications may be practiced within the scope of the appended claims.

## CLAIMS

What is claimed is:

1. An apparatus comprising:

a base;

an instrumentation subassembly having a body, wherein the instrumentation subassembly is coupled to the base, and wherein the body of the instrumentation subassembly is movable relative to the base about a first axis and a second axis, wherein the first axis is not parallel to the second axis, the instrumentation subassembly comprising:

a range detector associated with the body;

a first encoder that is configured to detect a degree of rotation about the first axis between the base and the body;

a second encoder that is configured to detect a degree of rotation about the second axis between the base and the body;

an orientation sensor that is configured to determine an orientation of a portion of the apparatus;

at least one processor; and

a memory in communication with the at least one processor, wherein the memory comprises instructions that, when executed by the at least one processor, cause the at least one processor to:

receive orientation data from the orientation sensor;

receive a first distance measurement indicative of a distance between the range detector and a first reference point;

receive a second distance measurement indicative of a distance between the range detector and a second reference point;

receive a third distance measurement indicative of a distance between the range detector and a first point on a drill rig;

receive rotation data from the first and second encoders, wherein the rotation data from the first and second encoders is associated with each of the first distance measurement, the second distance measurement, and the third distance measurement; and

determine, based on the orientation data from the orientation sensor, the first distance measurement, the second distance measurement, and the rotation data from the first and second encoders, a spacing between the first point on the drill rig and a first vertical plane.

2. The apparatus of claim 1, wherein the first vertical plane is parallel to a vertical reference plane that passes through the first reference point and the second reference point.

3. The apparatus of claim 1, wherein the first vertical plane is coplanar with a vertical reference plane that passes through the first reference point and the second reference point.

4. The apparatus of claim 2, wherein the first vertical plane is linearly offset from the vertical reference plane by a select distance.

5. The apparatus of claim 4, wherein the select distance is a user input.

6. The apparatus of claim 2, wherein the memory comprises instructions that, when executed by the at least one processor, cause the at least one processor to: cause an indication if the distance between the first point on the drill rig and the first vertical plane is within a tolerance.

7. The apparatus of claim 6, further comprising a marker laser associated with the body of the instrumentation subassembly, wherein the processor is configured to cause the indication if the distance between the first point on the drill rig and the first vertical plane is within the tolerance by activating the marker laser.

8. The apparatus of claim 1, wherein the first vertical plane is angularly offset by a select angle from a vertical reference plane that passes through the first reference point and the second reference point.

9. The apparatus as in claim 8, wherein the first vertical plane includes a target point.

10. The apparatus as in claim 9, wherein the select angle is a user input.

11. The apparatus of claim 2, wherein the memory comprises instructions that, when executed by the at least one processor, cause the at least one processor to:

receive a target distance measurement indicative of a distance to a target point; and

receive further rotation data from the first and second encoders, wherein the further rotation data is associated with the target distance measurement,

wherein the first vertical plane includes the target point.

12. The apparatus as in claim 6, further comprising an input device, wherein the memory comprises instructions that, when executed by the at least one processor, cause the at least one processor to receive an input of the tolerance.

13. The apparatus of claim 1, wherein the first axis is perpendicular to the second axis.

14. The apparatus of claim 1, wherein the orientation sensor is disposed within the body of the instrumentation subassembly, wherein the orientation sensor is configured to determine an orientation of the body of the instrumentation subassembly.

15. The apparatus of claim 1, wherein the range detector is a laser range detector.

16. The apparatus of claim 1, wherein the base comprises a tripod.

17. The apparatus of claim 1, wherein the orientation sensor comprises at least one gyroscope.

18. The apparatus of claim 1, wherein the orientation sensor comprises at least one accelerometer.

19. The apparatus of claim 1, wherein the memory comprises instructions that, when executed by the at least one processor, cause the at least one processor to:

measure a setup time; and

store the setup time in the memory.

20. A method of using the apparatus of any one of the preceding claims to align a drill rig with respect to a formation, the method comprising:

aiming the range detector at the first reference point;

aiming the range detector at the second reference point;

aiming the range detector at the first point on the drill rig; and

adjusting a position of at least a portion of the drill rig based on an output from the apparatus.

21. The method of claim 20, wherein the apparatus comprises a marker laser associated with the body of the instrumentation subassembly, wherein the output comprises an activation or an absence of activation of the marker laser.

22. The method of claim 20, wherein the apparatus comprises a display, wherein the output comprises the spacing displayed on the display.

23. The method of claim 20, further comprising:

aiming the range detector at the a second point on the drill rig; and

adjusting a position of at least a second portion of the drill rig based on a second output from the apparatus.

24. The method of claim 20, further comprising:

inputting, with the input device, at least one of a linear offset or an angular offset.

25. The method of claim 20, further comprising storing, in the memory, the first distance measurement and the rotation data from the first and second encoders.

26. An apparatus comprising:

a base;

an instrumentation subassembly having a body, wherein the instrumentation subassembly is coupled to the base, wherein the body of the instrumentation subassembly is movable relative to the base about a first axis and a second axis, wherein the first axis is not parallel to the second axis, the instrumentation subassembly comprising:

a first encoder that is configured to detect a degree of rotation about the first axis between the base and the body;

a second encoder that is configured to detect a degree of rotation about the second axis between the base and the body;

an orientation sensor that is configured to determine an orientation of a portion of the apparatus; and

one or more processors, wherein at least one processor of the one or more processors is in communication with the first encoder, the second encoder, and the orientation sensor.

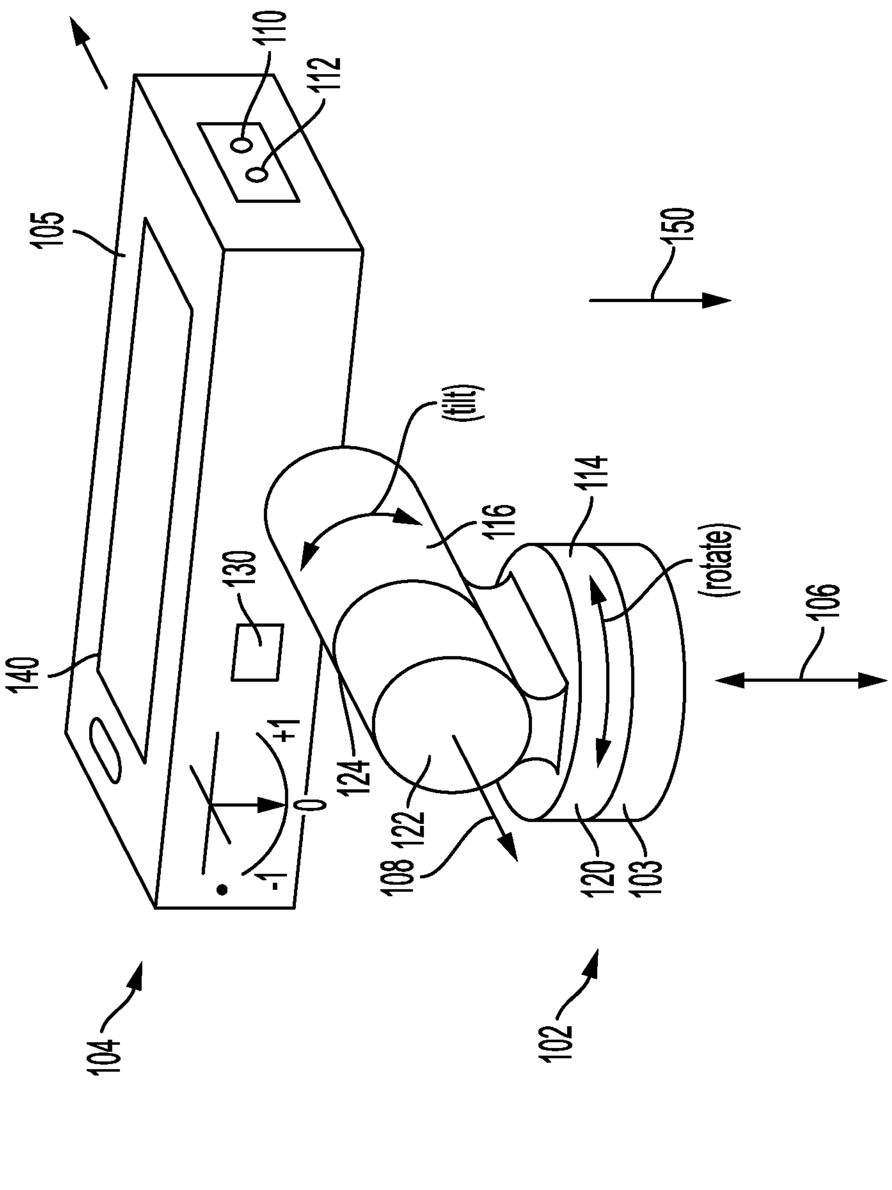
110
112
105
150
(tilt)
114
116
130
140
(rotate)
106
+1
0
-1
124
122
108
120
103
104
102

FIG. 1

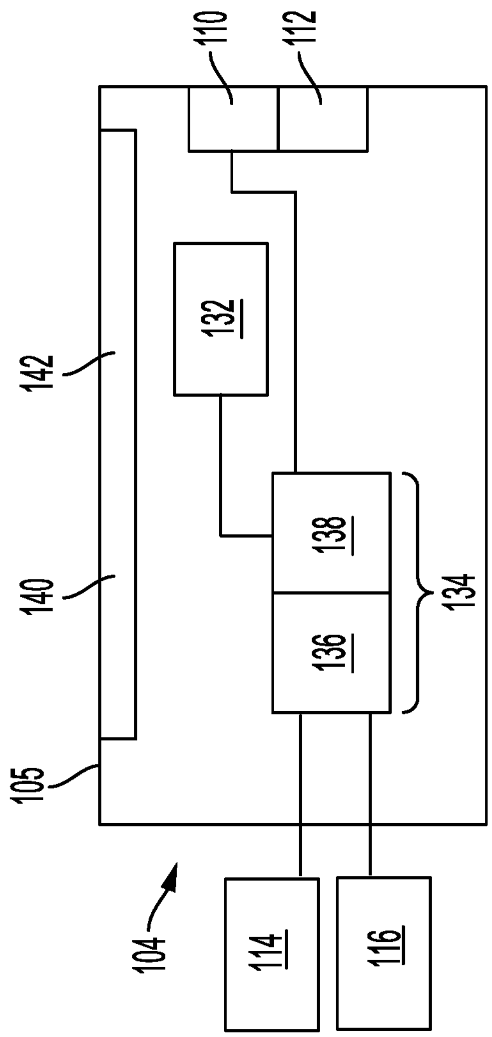


FIG. 2

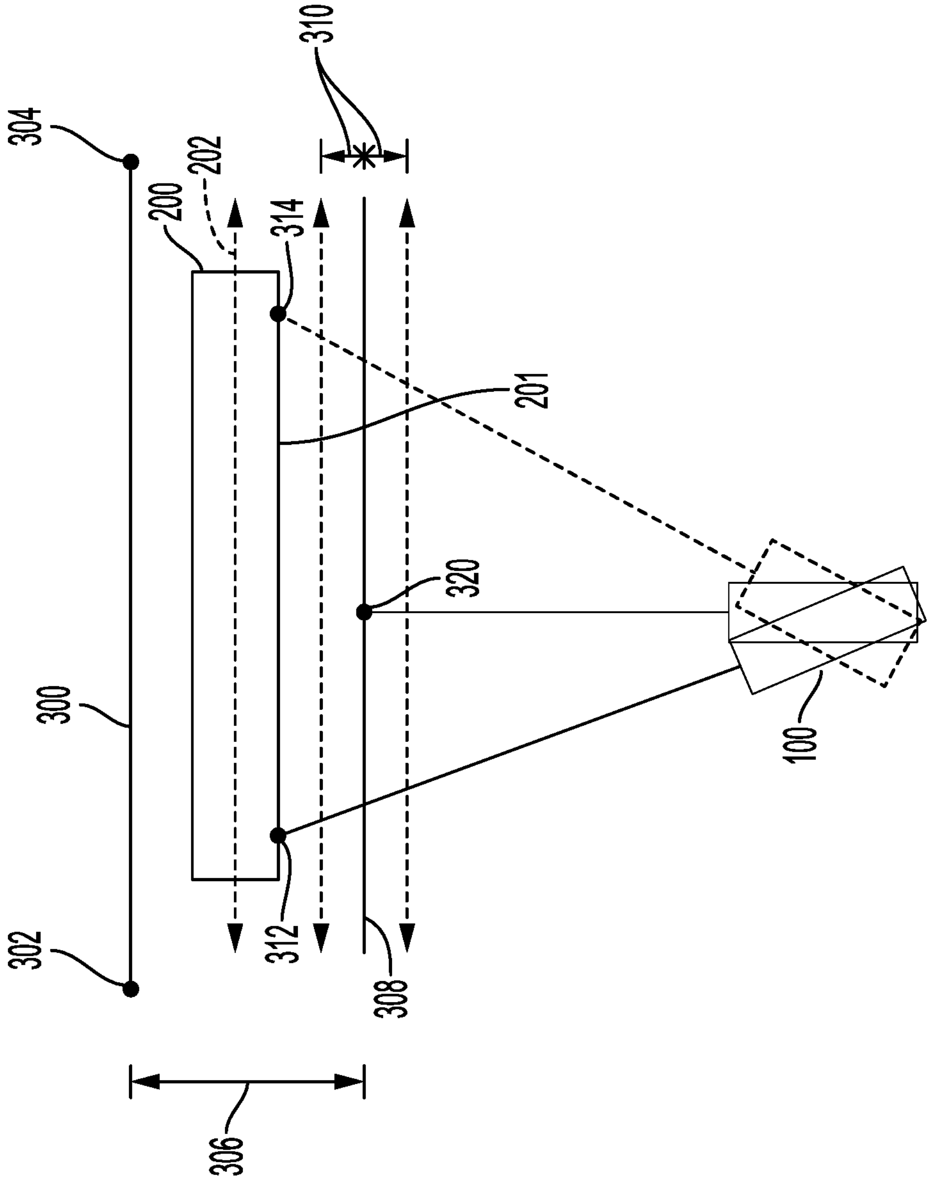


FIG. 3A

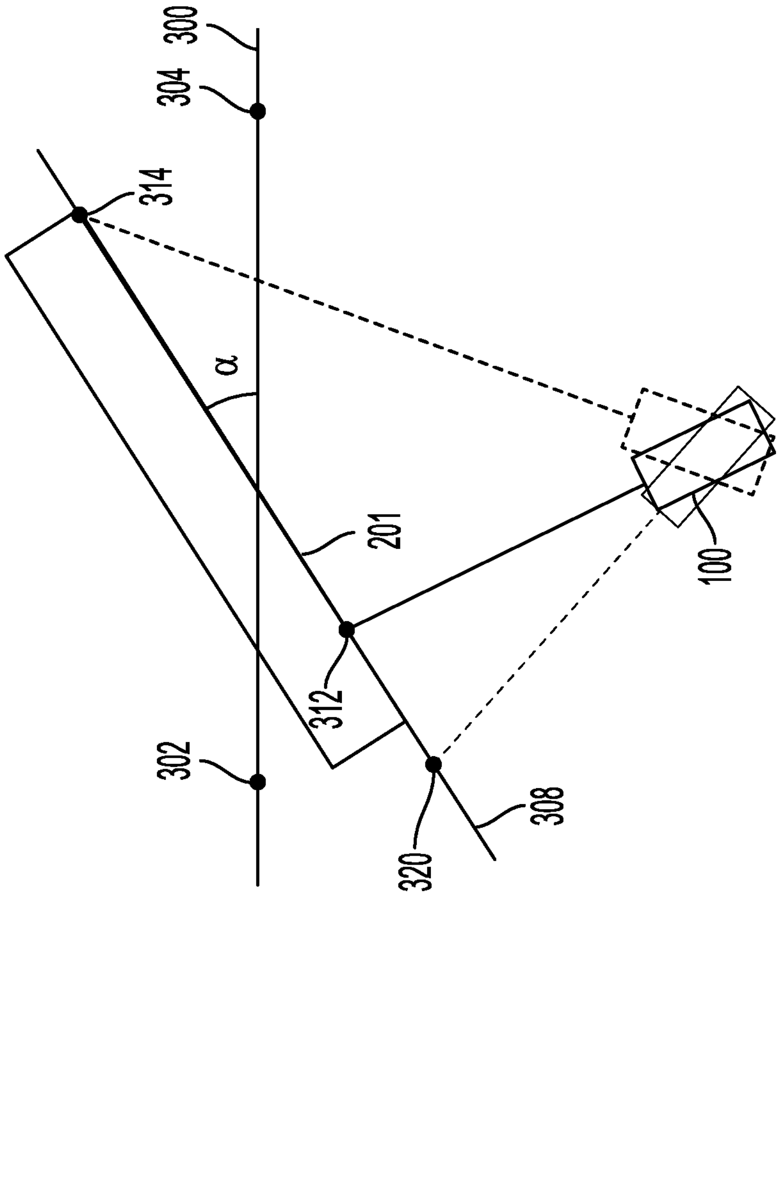


FIG. 3B

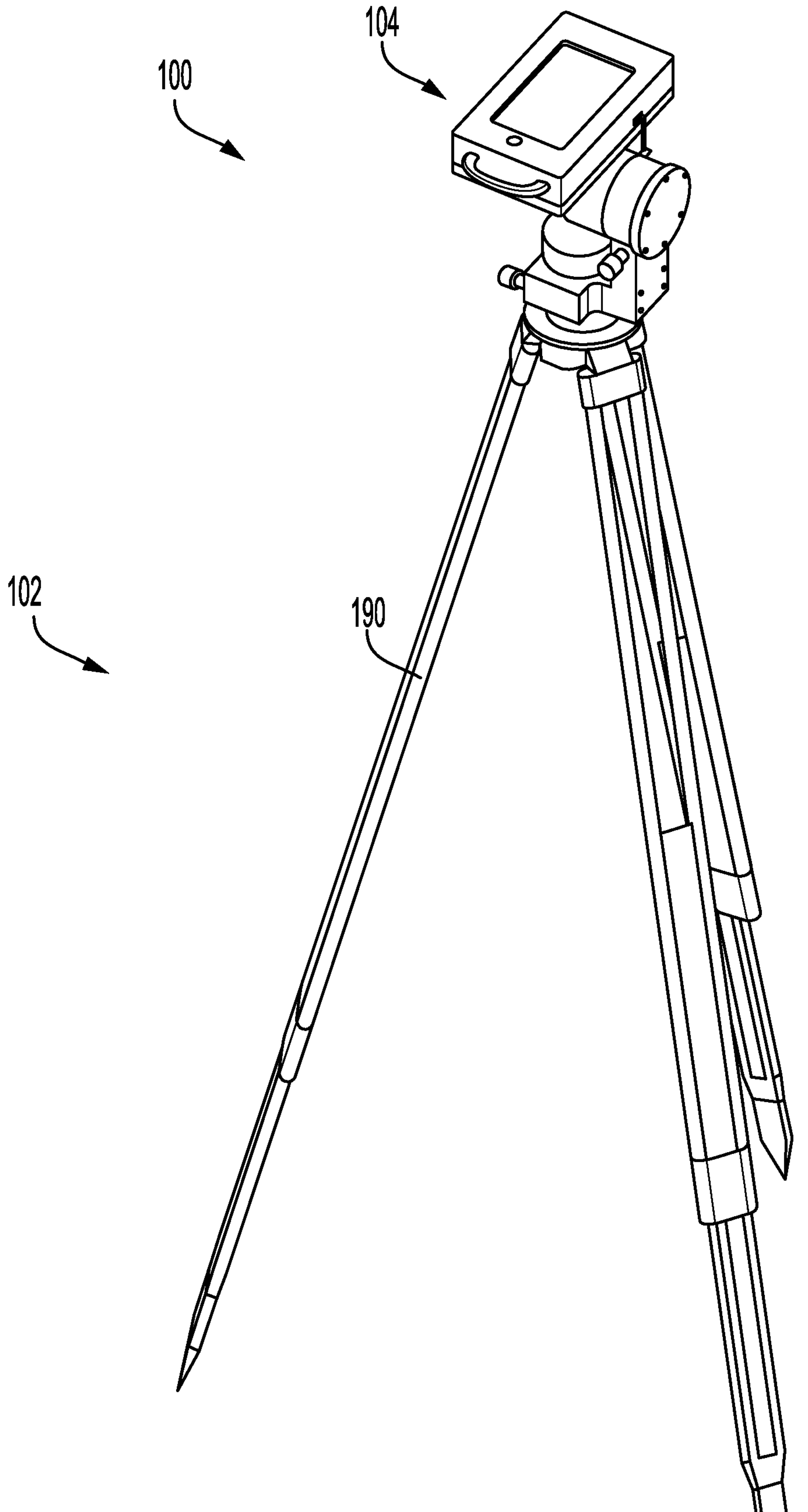


FIG. 4

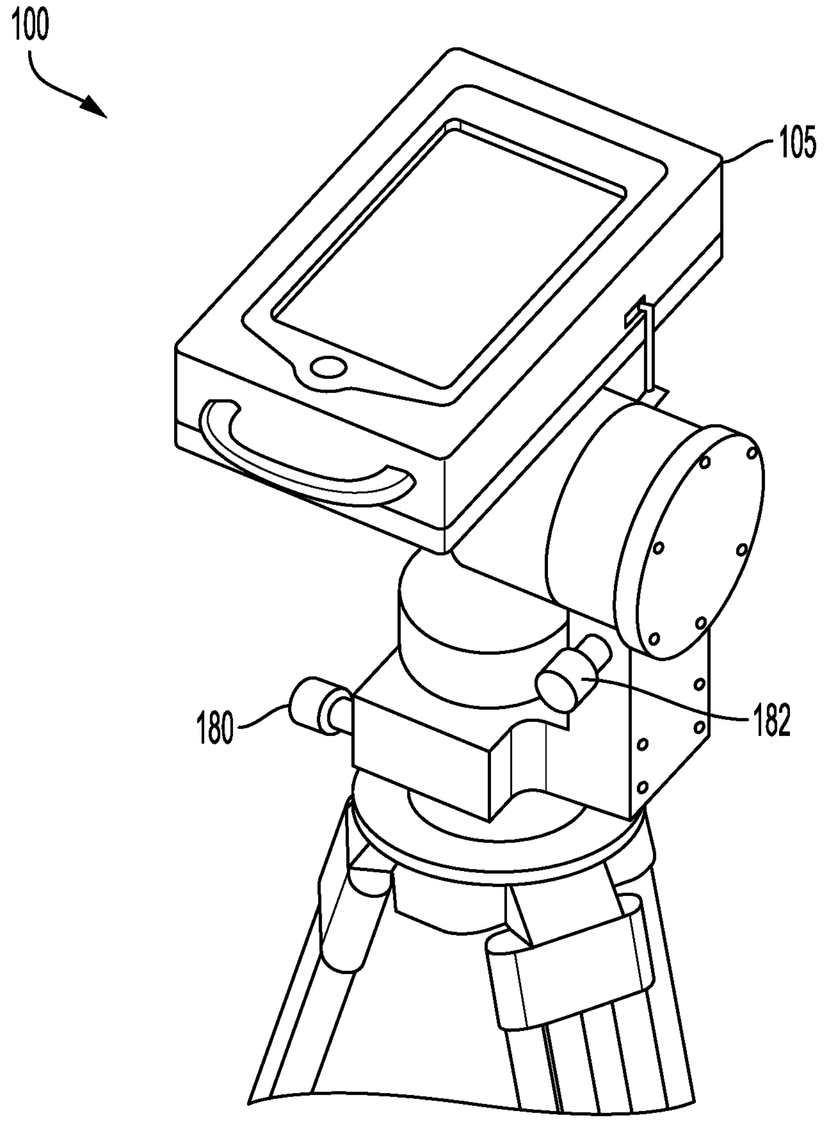


FIG. 5

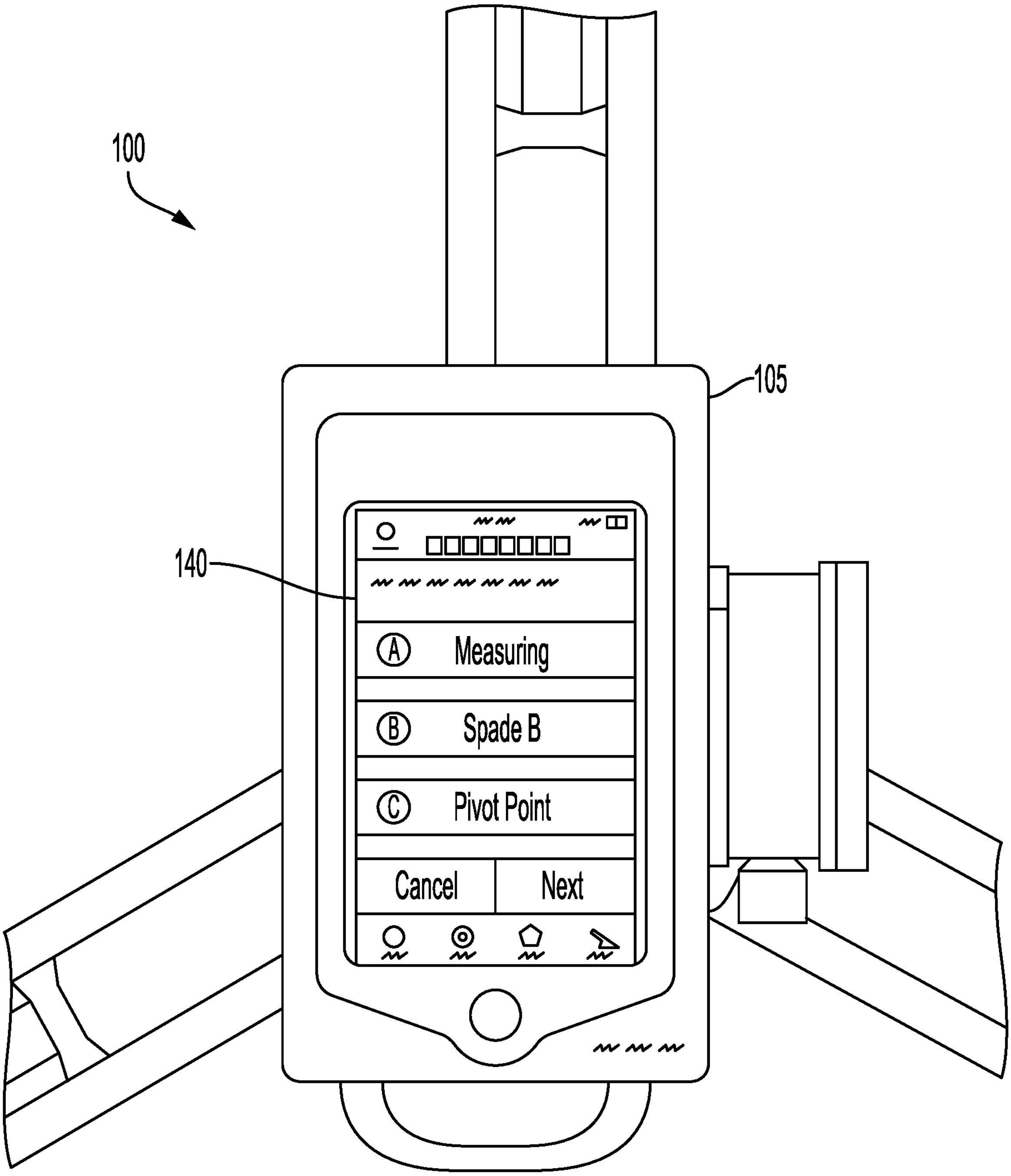


FIG. 6

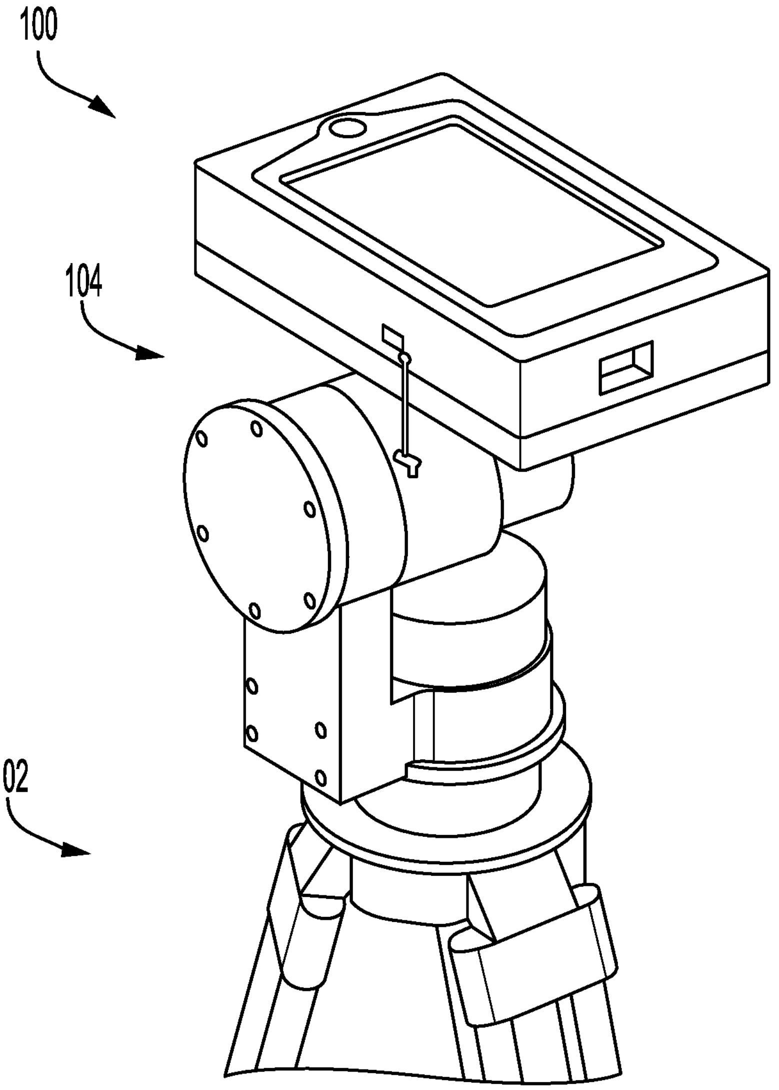


FIG. 7

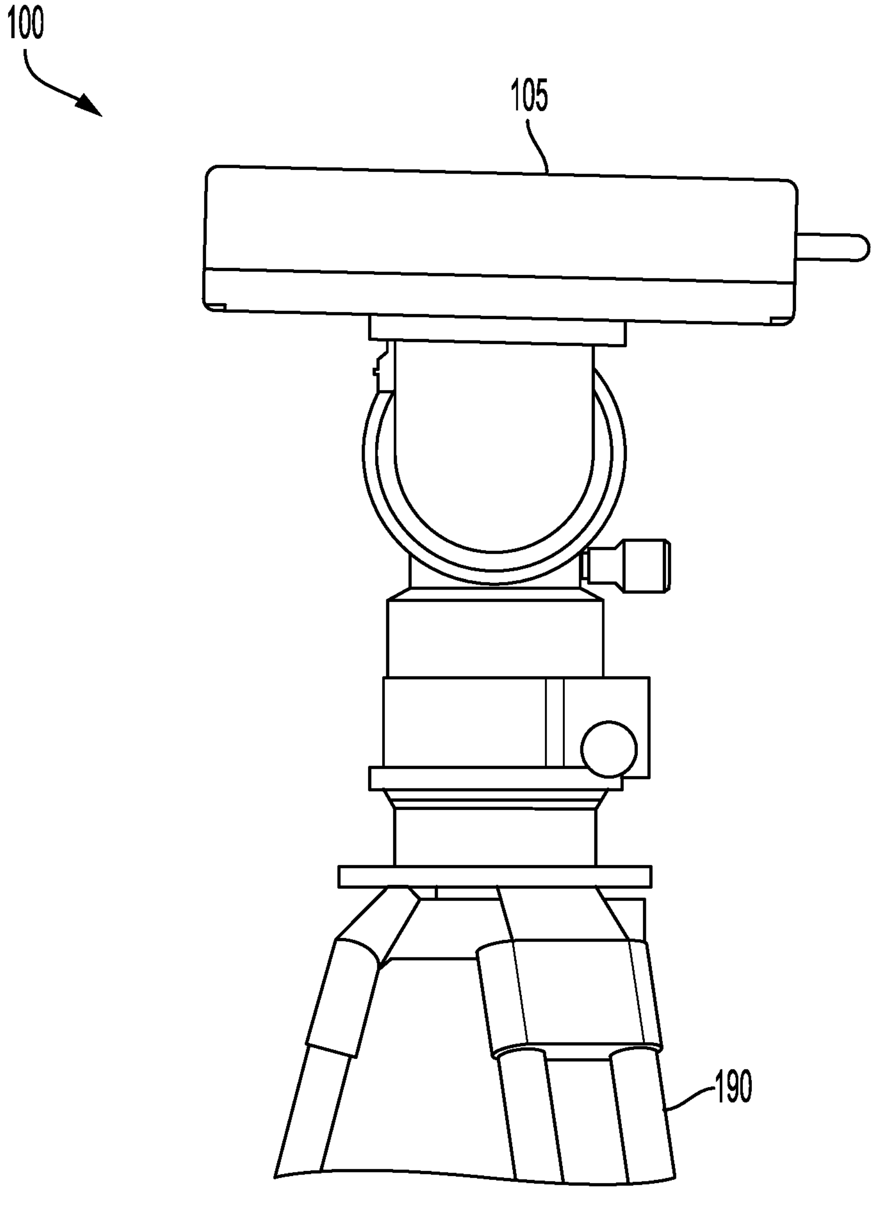


FIG. 8

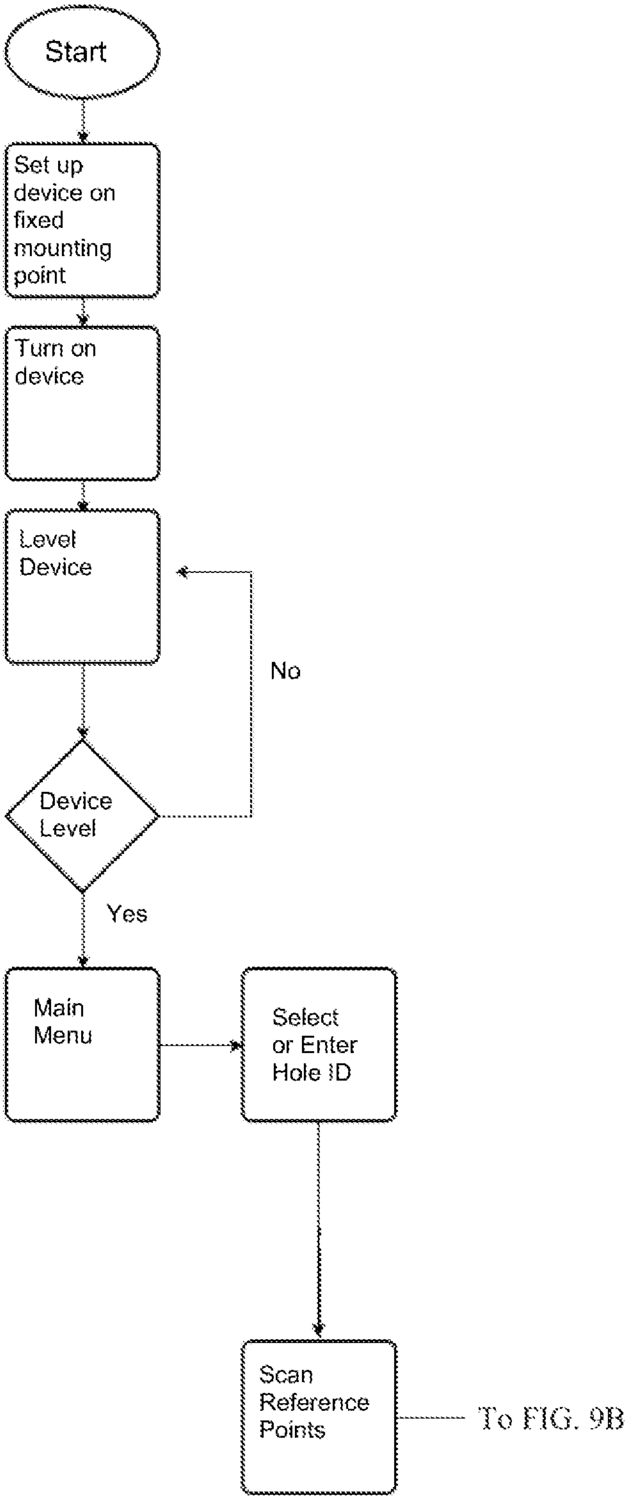
Start
Set up device on fixed mounting point
Turn on device
Level Device
No
Device Level
Yes
Main Menu
Select or Enter Hole ID
Scan Reference Points
To FIG. 9B

FIG. 9A

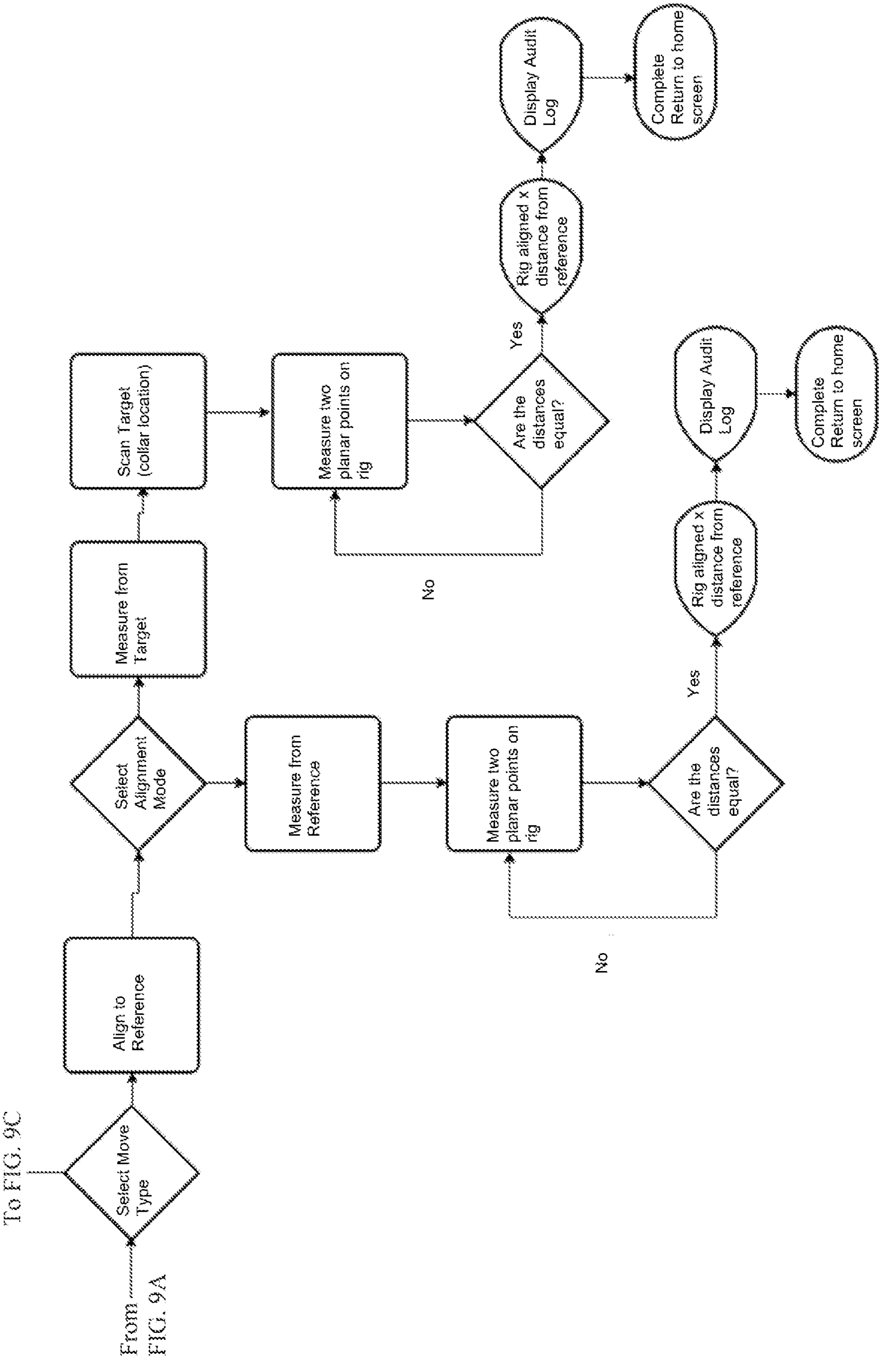
From FIG. 9A
To FIG. 9C
Select Move Type
Align to Reference
Select Alignment Mode
Measure from Target
Scan Target (collar location)
Measure two planar points on rig
Are the distances equal?
No
Yes
Rig aligned x distance from reference
Display Audit Log
Complete Return to home screen
Measure from Reference
Measure two planar points on rig
Are the distances equal?
No
Yes
Rig aligned x distance from reference
Display Audit Log
Complete Return to home screen

FIG. 9B

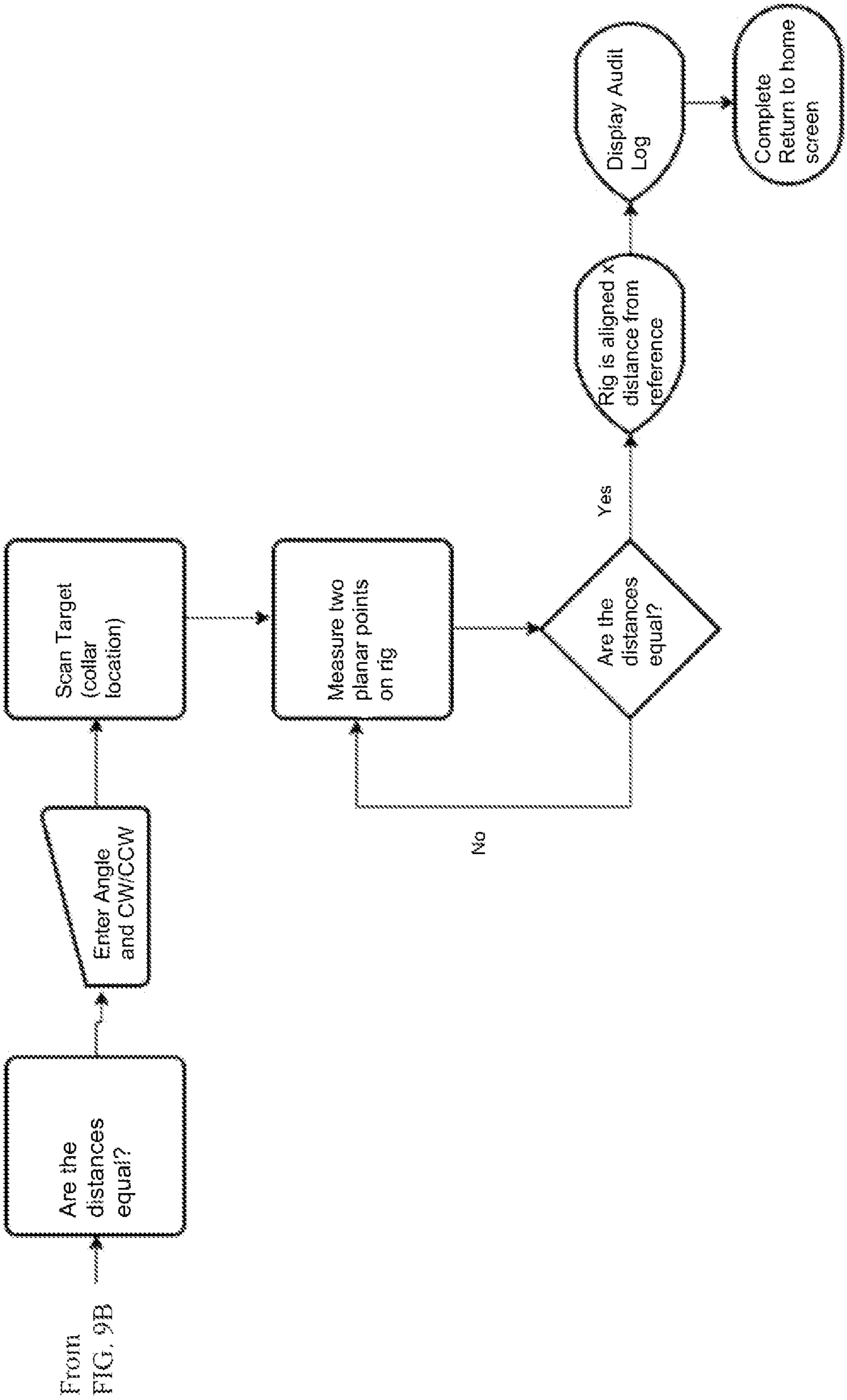
From FIG. 9B
Are the distances equal?
Enter Angle and CW/CCW
Scan Target (collar location)
Measure two planar points on rig
Are the distances equal?
No
Yes
Rig is aligned x distance from reference
Display Audit Log
Complete Return to home screen

FIG. 9C

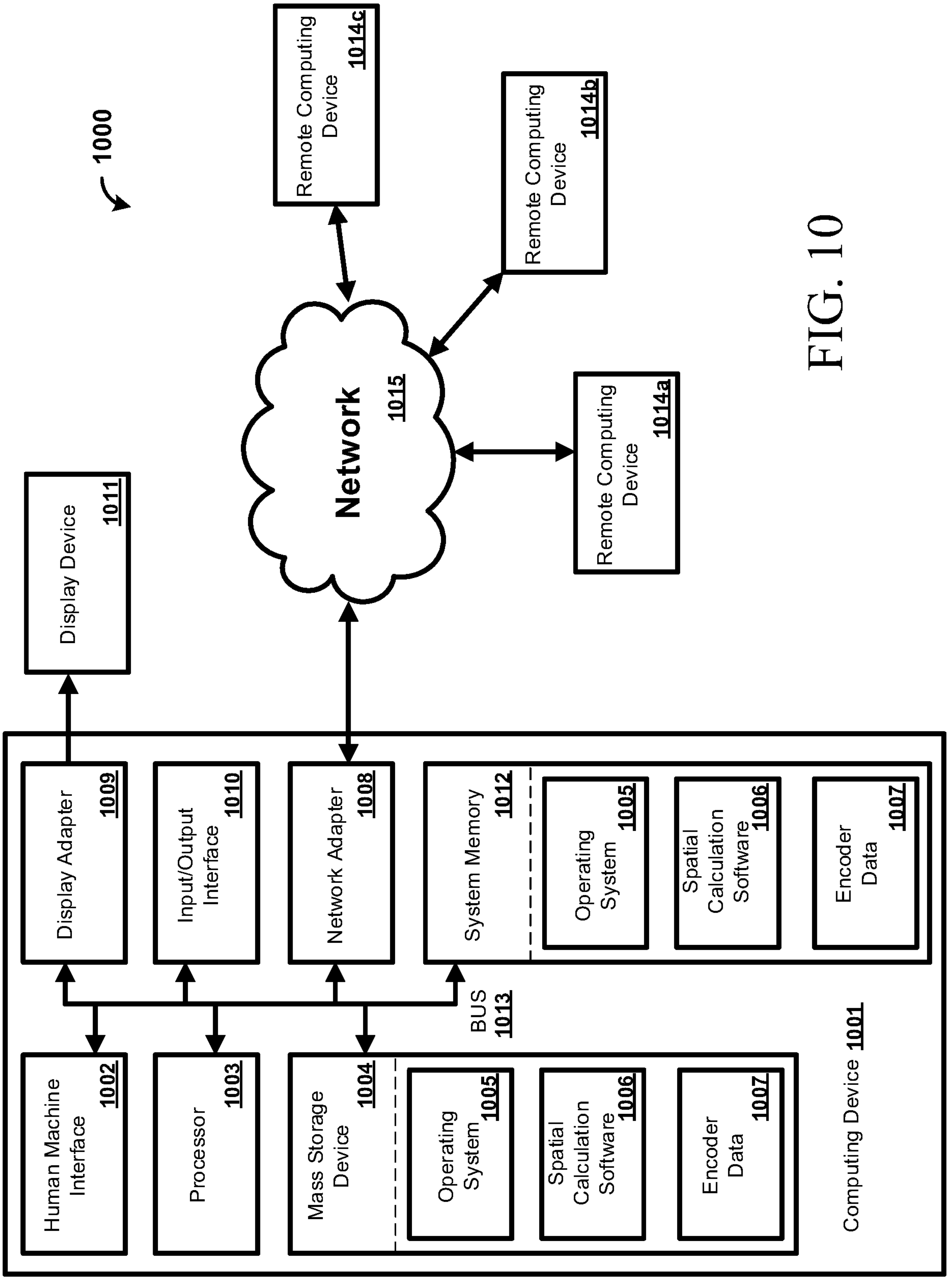
1000
Display Device
1011
Network
1015
Remote Computing Device
1014a
Remote Computing Device
1014b
Remote Computing Device
1014c
Display Adapter
1009
Input/Output Interface
1010
Network Adapter
1008
System Memory
1012
Operating System
1005
Spatial Calculation Software
1006
Encoder Data
1007
BUS
1013
Human Machine Interface
1002
Processor
1003
Mass Storage Device
1004
Operating System
1005
Spatial Calculation Software
1006
Encoder Data
1007
Computing Device 1001

FIG. 10

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 21/19961

A. CLASSIFICATION OF SUBJECT MATTER
IPC - E21B 12/00, 47/02; G01S 17/42, 7/48; G01B 11/26, 11/27; G01C 1/02, 3/08, 15/00 (2021.01)
CPC - E21B 12/00, 47/02; G01S 17/42, 7/48; G01B 11/26, 11/27; G01C 1/02, 3/08, 15/002

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
See Search History document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y<br>---<br>A | WO 2019/033170 A1 (FASTBRICK IP PTY LTD) 21 February 2019 (21.02.2019) entire document, especially Fig. 2, para [0080], [0082], [0087], [0089], [0114], [0115] | 1-18, 20-22, 24-26<br>---<br>19, 23 |
| Y<br>---<br>A | WO 2019/126864 A1 (APOSYS TECHNOLOGIES INC.) 04 July 2019 (04.07.2019) entire document, especially Fig. 1A, para [0041], [0045], [0048], [0051], [0055]-[0057], [0059], [0072], [0080], [0082], [0083], [0087], [0090], [0120], [0131], [0138] | 1-18, 20-22, 24-26<br>---<br>19, 23 |
| Y<br>---<br>A | WO 2017/027925 A1 (PRECISION ALIGNMENT HOLDINGS PTY LTD) 23 February 2017 (23.02.2017) entire document, especially para [0092], [0094], [0096], [0105] | 1-18, 20-22, 24, 25<br>---<br>19, 23 |
| A | US 2018/0361595 A1 (THE BOEING COMPANY) 20 December 2018 (20.12.2018) entire document, especially para [0072] | 19 |

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 23 April 2021 | MAY 19 2021 |

| Name and mailing address of the ISA/US | Authorized officer |
|---|---|
| Mail Stop PCT, Attn: ISA/US, Commissioner for Patents<br>P.O. Box 1450, Alexandria, Virginia 22313-1450<br>Facsimile No. 571-273-8300 | Lee Young<br>Telephone No. PCT Helpdesk: 571-272-4300 |